1985 Annual Report

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INTERNATIONAL JOINT COMMISSION

GREAT LAKES SCIENCE ADVISORY BOARD
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June 1985

International Joint Commission

Canada and the United States

Commissioners:

The Great Lakes Science Advisory Board, in partial fulfillment of its responsibilities under the Great Lakes Water Quality Agreement of 1978, is pleased to submit its 1985 Annual Report to the Commission.

In this report the Board describes its ongoing efforts to assess the sources and effects of persistent toxic substances on the health of the Great Lakes ecosystem and summarizes the findings and recommendations of its various committees.

In the past year the Board underwent many changes in membership, including the appointment of a new co-chairman and incorporating a number of social and economic scientists. As a result, the Board spent a considerable amount of time re-assessing its role and structure. Many changes were made, including the formation of a Council of Great Lakes Research Managers and a restructuring of the Board's standing committees and task forces. The Board feels that these administrative and structural changes will contribute to considerable progress.

Respectfully submitted,

Gilles LaRoche
Chairman
Canadian Section

Ruth A. Reck
Acting Chairman
United States Section

May 8, 1985

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Summary

The Science Advisory Board is the scientific advisor to the International Joint Commission. Its membership represents a wide range of disciplines, including: aquatic biology, toxicology, human health, chemistry, engineering, atmospheric physics, pharmacology, business and economics, political science and environmental law. The Board has five standing committees and six task forces (Figure 1) and this report describes the activities of these groups and their conclusions. The workplan addressed three broad areas concerning water quality in the Great Lakes.

The major program areas resulting from the 1972 and 1978 agreements are:

- Assessment of inputs of materials to the Great Lakes.
- Assessment of changes in the Great Lakes ecosystem resulting from inputs of these materials.
- Management of the Great Lakes to sustain the ecosystem for the beneficial use of all lifeforms.

In summary, the SAB activities in 1984-85 were:

ACTIVITIES RELATED TO SOURCES

The Atmospheric Task Force was reconstituted to investigate deposition to the Great Lakes. A contract was released to identify existing networks in the Basin that measure and estimate deposition.

The Groundwater Task Force was reformulated to identify the availability of adequate hydrogeologic maps for use in identifying areas of possible groundwater contamination.

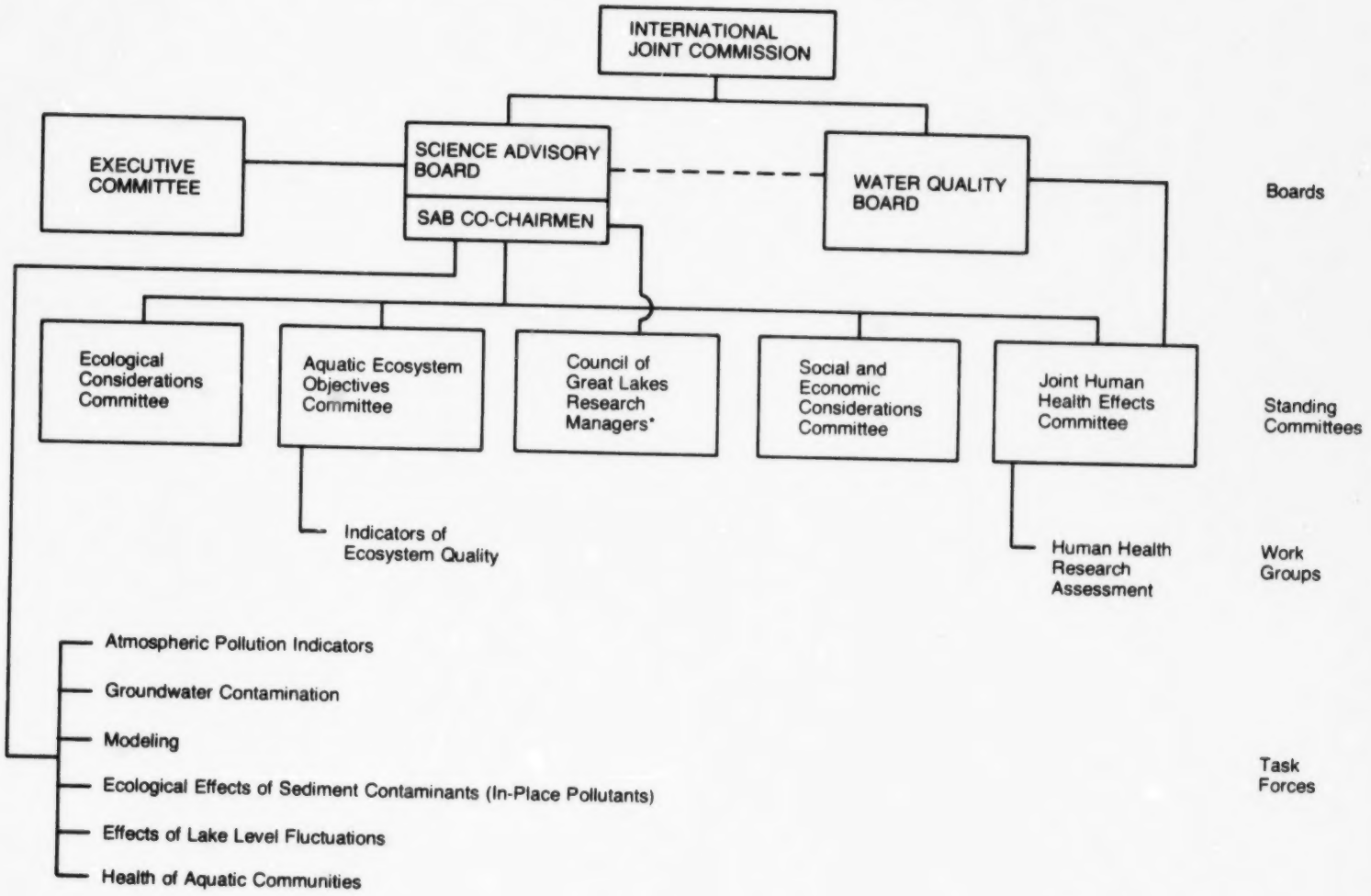
The Ecological Effects of Sediment Contaminants Task Force held a workshop to evaluate the significance of sediment contamination and develop remedial measures for in-place pollutants.

ACTIVITIES RELATED TO IMPACTS

The Ecological Considerations Committee was formed to advise the Board on impacts of human activity on the health and quality of the Great Lakes.

The Health of Aquatic Communities Task Force examined existing data on the effects of toxic chemicals on aquatic communities and is organizing a workshop on assessing aquatic community health.

FIGURE 1: ORGANIZATION CHART OF THE SCIENCE ADVISORY BOARD



*The Council of Great Lakes Research Managers report only to the SAB Co-Chairmen.

The Council of Great Lakes Research Managers is assessing the adequacy of Great Lakes research and identifying research needs.

The Human Health Effects Committee is assessing the risk associated with chemicals identified in the Great Lakes ecosystem.

ACTIVITIES RELATED TO MANAGEMENT

The Modeling Task Force is preparing a report on models used in the management of the Great Lakes environment.

The Social and Economic Considerations Committee has reviewed institutional arrangements by examining consensus management in Green Bay.

The Aquatic Ecosystem Objectives Committee has proposed revised water quality objectives for lindane, ammonia and toxaphene, and developed ecosystem objectives by investigating lake trout as an indicator of oligotrophy.

Recommendations

Based upon reports submitted by the committees, the Science Advisory Board makes the following recommendations to the International Joint Commission.

1. Groundwater Task Force:

   A study be commissioned to prepare a hydrogeologic inventory of the Great Lakes Basin for purposes of assessing the potential for their contamination and be based upon the study design of the Task Force.

2. Atmospheric Task Force:

   (a) *A standard protocol for measuring organics in atmospheric media (precipitation, airborne particles and vapour phase organics) be developed by the Parties;*

   (b) *A standard protocol that ensures compatible measurements of metal ions be established (including the identification of a preferred digestion and instrumentation technique); and*

   (c) *Intercomparison studies be initiated to assess the comparability and quality of analytical results from various laboratories involved in atmospheric deposition monitoring networks.*

3. Ecological Effects of Sediment Contaminants:

   (a) *It is recommended that the Parties embark on management strategies for the rehabilitation of two Areas of Concern, such as Hamilton Harbour and Grand Calumet, and to observe the biological processes and the rates at which recovery occurs.*

   (b) *As adjunct to the preceding recommendation, the Parties should proceed with a social and economic investigation of the costs and benefits associated with the rehabilitation of the Areas of Concern selected in 3a.*

4. Human Health Effects Committee:

   (a) *The jurisdictions should continue to monitor lead concentrations in fish in the St. Lawrence River so that potential human exposure can be assessed reliably.*

(b) *The jurisdictions should analyze the edible portions of Great Lakes fish for both organic and inorganic species of lead.*

5. Aquatic Ecosystem Objectives Committee:

(a) *It is recommended that the ammonia objectives be revised to raise the open waters limit for aquatic life from 0.02 to 0.03 mg/L un-ionized ammonia.*

(b) *It is recommended that the concentration of total hexachlorocyclohexane (BHC) isomers in water should be revised to not exceed 0.02 ug/L for the protection of aquatic life. The concentration of total BHC isomers in edible portions of fish should not exceed 0.3 mg/kg (wet weight) for the protection of human consumers of fish.*

(c) *It is recommended that work be continued on the further development of indicators of ecosystem health, including the selection of species or communities for mesotrophic and eutrophic systems.*

6. Modeling Task Force:

(a) *Because the transfer of scientific information from modelers to managers and policy makers has been insufficient, it is recommended that new approaches involving the use of personal computers, and the development of intelligible, user-friendly software for water quality modeling should be encouraged.*

(b) *Integrated and multifaceted Great Lakes model development, like Great Lakes ecosystem research, is a long-term endeavor that will be best served by a continuity of support. The building of new model structures is also encouraged and greater support for refining and integrating existing models is strongly recommended.*

Preamble

The objective of the 1978 Great Lakes Water Quality Agreement is clearly one of rehabilitation and conservation of the Great Lakes through the elimination of pollutants, which represents the philosophy of our societies and the International Joint Commission. Both the Water Quality Board and the Science Advisory Board in their annual presentations to the Commission in Indianapolis in 1983 stated that they recognized that a shift is taking place in the environmental management of the Great Lakes. The continuing recovery of the Lakes in response to phosphorus management is creating a more desirable resource, the use of which demands an increased understanding of user needs, interactions and benefits. Resource management in a multi-user context thus represents a strategy to realistically achieve the objectives of the 1978 Agreement within the confines established by sound socio-economic analyses and requirements.

In its 1982 and 1983 reports, the Board identified critical areas where knowledge gaps remained. The efforts of the Board have continued in these areas:

(1) The effects of persistent toxic substances on aquatic communities.

(2) The significance of atmospheric pollution.

(3) The significance of groundwater contamination.

(4) The application of computer models.

(5) Incorporating social and economic considerations.

(6) The effects of hazardous substances on human health.

In addressing these subjects, the Science Advisory Board has standing committees on socio-economic considerations, human health effects and ecosystem objectives. It has also established an Ecological Considerations Committee, Atmospheric and Groundwater Task Forces and a Council of Great Lakes Research Managers.

The 1984-85 workplan of the board addressed three broad areas:

1. Assessment of inputs of materials to the Great Lakes.

2. Assessment of changes in the Great Lakes ecosystem resulting from inputs of these materials.

3. Management of Great Lakes inputs to sustain the ecosystem for the beneficial use of all lifeforms, including humans.

This report identifies the work conducted by the Board and provides its recommendations to the Commission.

1. Monitoring and Research for Certain Sources of Contaminants

While the United States and Canada direct a considerable effort towards identifying anthropogenic inputs to the Great Lakes, there still exist uncertainties regarding the importance of those sources. The two major categories of materials whose inputs to the Great Lakes have either originated or increased from human activity are nutrients and toxic materials. Nutrients affect the Lakes by increasing eutrophication and toxic substances may effect changes in the morphology, reproductive capability and ultimate viability of aquatic and wildlife populations indigenous to the Lakes, including man. Relative contributions must be known, and while point sources are monitored and loadings can be estimated, a number of sources are still not adequately quantified. Of particular interest are groundwater, the atmosphere, and in situ sediments.

1.1 GROUNDWATER CONTAMINATION

1.1.1 Background

In 1983, the Board found deficiencies in knowledge about groundwater contamination in the Great Lakes Basin and about groundwater movements. These findings were of concern to the Board since areas of the Great Lakes Basin are characterized by intensive land use activity and potential for contamination.

One of the needs identified by the Board was for mapping of groundwater conditions around and under the Great Lakes Basin. Data on geology and hydrogeology, soils, depth to water tables, type and depth of bedrock, land use, population densities and pollution sources have not been integrated for the entire Great Lakes although some agencies have compiled data in their jurisdiction. Moreover, some of the existing physical and cultural data appear deficient.

In 1985, the Board initiated the mapping of hydrogeologic regimens of the Great Lakes Basin. The study design described in the report of the Groundwater Task Force outlines the scope and content of the needed work.

1.1.2 Study Design Summary

Objectives of Study

The objectives of the proposed study are to define the major hydrogeological regimens of the Great Lakes Basin and to assess the potential for the groundwater in these regimens to carry contaminants into the Great Lakes and vice-versa.

Specifically, the study will attempt to define the hydrogeologic units within the Great Lakes Basin; to locate major areas of potential contamination through the use of land; to evaluate the potential for these contaminants to move through the hydrogeologic units into the Great Lakes; and to examine the significance of various contaminant discharges. A result of this work will be an identification of areas where the contamination potential is the greatest such that the Commission can recommend to various governments areas that should be investigated or contaminants be mitigated.

(i) Scope and Content

The study design calls for the preparation of a series of geologic, hydrologic and cultural maps identifying areas and fulfilling four conditions:

(1) there must be a source or sources of contamination;

(2) hydrogeologic conditions must exist that would permit the transport of contaminants into the water table and through the aquifer;

(3) the flow paths must be short enough in distance and time that dilution or decomposition of the contaminants will be minor; and

(4) direction of flow must be toward the Lakes or their tributaries.

The geologic, hydrologic and cultural maps will be used to develop maps identifying:

(1) Areas of Concern based on hydrogeologic conditions and land use activities;

(2) identification of the fastest flowing hydrogeologic regimens with the greatest potential for contamination (hot spots) of the Great Lakes; and

(3) the location and extent of existing studies to assist in the identification of areas posing a threat to the Great Lakes water quality where limited information as to hydrogeology and sources of contamination exists.

The derived summary maps will for the first time characterize Areas of Concern in which the Great Lakes may be contaminated through groundwater flows, the maps will:

(1) mark the first attempt at integrating information on contamination of the entire Great Lakes by groundwater;

(2) identify those areas of the Basin where insufficient information about groundwater conditions exists;
(3) serve as a comprehensive groundwater-surface water monitoring strategy for the Great Lakes in accordance with Annex 11 1(d) of the 1978 Great Lakes Water Quality Agreement (GLWQA);
(4) identify areas where chemical residues in the sub-surface regime should be characterized;
(5) provide a state-of-the-art review of existing hydrogeologic mapping techniques;
(6) offer insights on abatement of point and non-point sources of groundwater contamination, regional land-use planning and water resource management needs; and
(7) lead to recommendations on groundwater research needs.

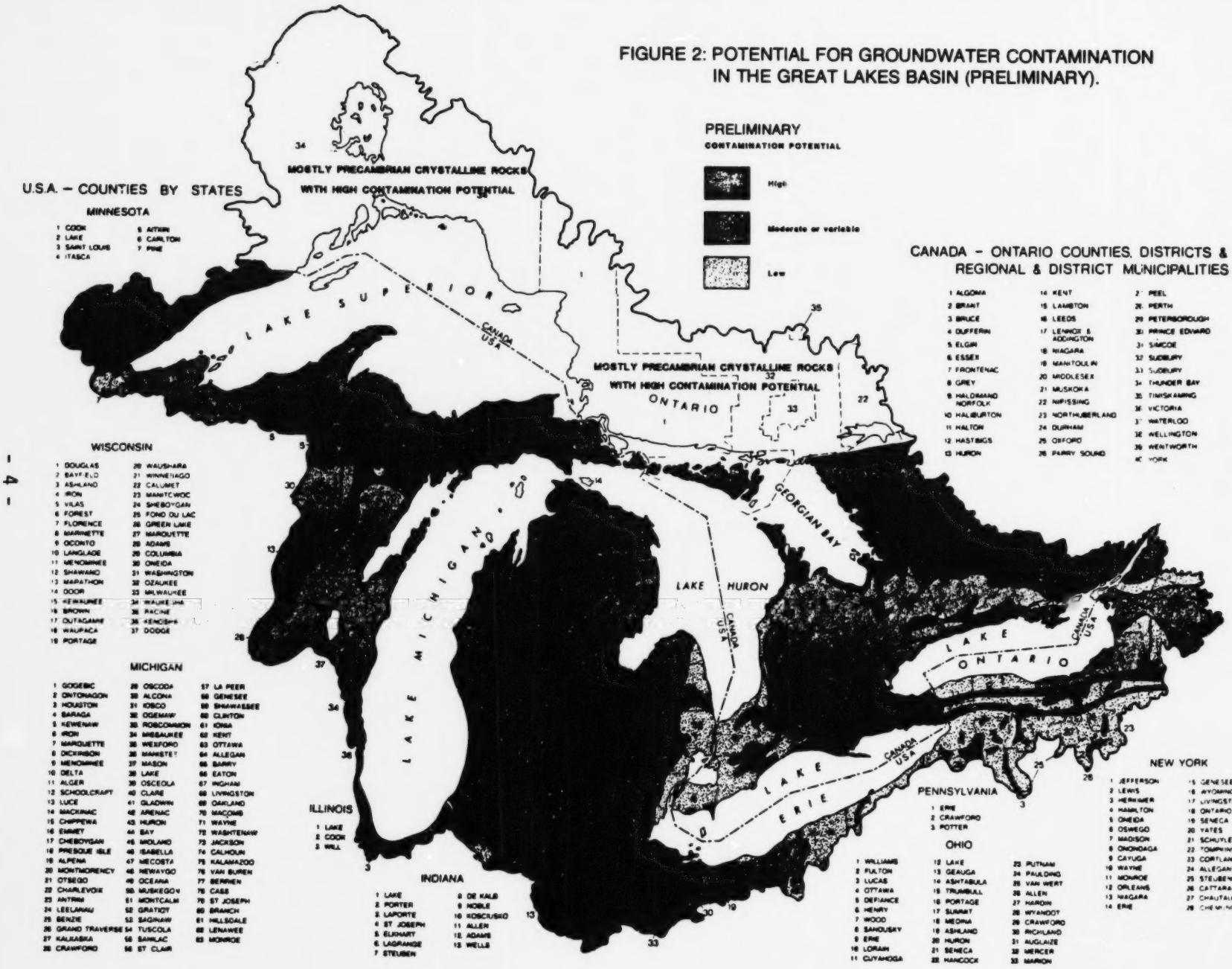
An example of an interpretative summary map to be produced is displayed in Figure 2. The map depicting the groundwater contamination potential of areas in the Great Lakes Basin was produced using overlays of previously developed maps of drift permeability and thickness, land use, potential sources of contamination and near-surface aquifer units. Although this map is heavily biased by the type of materials found because of soil and bedrock conditions, it does show that areas of the Basin characterized by sand and gravel or near to surface carbonate rock aquifers have a high potential for contaminating the Great Lakes. Low permeablity near surface aquifer units have a low potential of contaminating the Great Lakes. The preliminary contamination potential map thus substantiates the need for further work in this area.

(ii) Methodology

The study design recommends that mapping be done at a 1:1,000,000 scale. This represents a compromise between available mapping at a regional scale while also being of sufficient depth to give a good indication of the areas of the Basin that have a potential for contaminating the Great Lakes via groundwater. The work is proposed to be undertaken in three phases over a 1 to 1-1/2-year period at an estimated cost of $200,000.

Phase I will involve a state-of-the-art review of the hydrogeologic regime and interpretive mapping methodologies to be applied to the Great Lakes. Phase II will involve the collation of information and maps that will define the hydrogeologic regimens and land use activities of the Great Lakes Basin. The information collected during Phase II will be synthesized and displayed on maps. Phase III will largely involve "finger-printing" the hydrogeologic regimens as to their hydraulic properties, proximity to and severity of contamination sources to the Great Lakes or their tributaries. These maps will be used to produce the summary interpretative maps identifying the hydrogeologic regimes and the attendant potential for groundwater in these regimes to carry contaminants into the Great Lakes.

FIGURE 2: POTENTIAL FOR GROUNDWATER CONTAMINATION IN THE GREAT LAKES BASIN (PRELIMINARY).



Land Use and Pollution Sources

Potential groundwater contamination from diffuse sources such as urban runoff, fertilizers and pesticides spread over lands and road salt over highways will depend on the amount, type and toxicity of the contaminants and the proximity of water-transmitting aquifer units. Point sources such as waste disposal sites, dumping and spillage, and septic tank systems are more apt to initially contaminate smaller volumes of water but with concentrations much higher than from diffuse sources.

Much of the land use and pollution source inventories will be synthesized and displayed onto appropriate maps.

Susceptibility to Contamination

Having confirmed potential sources of contamination the next concern is whether the hydrogeologic materials will allow the contaminants to enter groundwater systems.

In the United States, the Illinois State Geological Survey has developed maps based upon a combination of hydrologic properties and stratigraphic sequences of geologic materials between the surface and a depth of 50 feet. For Michigan, Western Michigan University (1981) has mapped aquifer vulnerability to surface contamination.

It should be noted, however, that groundwater susceptibility to contamination mapping only gives an indication of the potential for contamination; seldom are the actual locations of pollution sources considered at all depths.

Aquifer Flow Characteristics

Information on groundwater flow is limited. It is known, however, that contaminants do not mix readily with this water and may travel slowly as well-defined slugs or plumes.

Characterization and subsequent mapping of aquifer movements is extremely complex. For example, a short circuit of the groundwater flow path can exist if the water table is intercepted by a stream channel, therefore, travel time of a contaminant to the Great Lakes becomes reduced. It is suspected that of the 1,132 cms (40,000 cfs) average runoff from the U.S. portion of the Basin, approximately 37 percent is derived from groundwater as base flows to the streams; based on 70% flow duration (Waller and Allen, 1975). Because of the predominance of low permeability deposits on the Canadian side of the Basin, the average annual contribution of groundwater to streamflow is estimated to be less than 20% (Ontario Ministry of Natural Resources, 1984). Work by Cartwright et al. (1979) and Anderson et al. (1984) has added a further dimension to the consideration of groundwater

flows to the Lakes. According to geophysical measurements of nearshore bottom sediments in Lake Michigan, substantially more lake water is coming from aquifers below the Lakes than previously suspected.

Direction of Flow

Once an aquifer has been contaminated and hydrogeological conditions exist that would permit the transport of contaminants through the groundwater system, the direction of flow must be toward the Lakes or tributaries for Great Lakes contamination to occur. As a general "rule-of-thumb", groundwater divides generally coincide with surface-water divides under natural conditions. Exceptions can arise in areas where there is heavy pumping, such as in the Chicago and Milwaukee areas. The surface-water divide in this area extends only a few miles from Lake Michigan; however, the groundwater divide in the bedrock aquifer extends tens of miles beyond.

In general, however, little is known of the direction of groundwater flow in or out of the Great Lakes Basin or about water table elevations. The extensive drawdown cones in the Chicago/Milwaukee area, for example, have resulted in groundwater flow to be away from Lake Michigan and the Mississippi River and into the area.

1.1.3 Conclusions

Both non-point and point sources of pollution are found in areas of the Basin susceptible to groundwater contamination. In turn, hydrogeologic pathways exist in the Basin that would permit a relatively rapid movement of contaminated groundwater to the Great Lakes. Based on a hydrologic budget calculation, it is estimated that approximately 30 percent of the tributary flow into the Great Lakes is derived from groundwater. Furthermore, recent research findings also suggest that the direct flow of water from aquifers to the Lakes is greater than previously suspected.

Data on hydrogeologic regimens and potential for contamination of the Great Lakes already exist in public files. Information on pollution sources, land use and hydrogeology of the Great Lakes Basin is also available. It is estimated that groundwater reports consider 80 percent of the Basin although many will only furnish partial hydrogeologic information. Much of this information, however, has not been collated and mapped.

The Board has developed a study design for an integrated mapping of those hydrogeologic regimens of the Great Lakes Basin which have potential for contaminating the Great Lakes; therefore, it is recommended that:

- A STUDY BE COMMISSIONED TO PREPARE A HYDROGEOLOGIC INVENTORY OF THE GREAT LAKES BASIN FOR PURPOSES OF ASSESSING THE POTENTIAL FOR THEIR CONTAMINATION; and

- THE COMMISSIONED STUDY BE BASED UPON THE STUDY DESIGN OUTLINED IN THIS REPORT.

1.2 ATMOSPHERIC DEPOSITION

The significance of atmospheric exchange of contaminants to the Great Lakes has become the focus of attention for nutrients, toxics, trace metals and conservative species. Early work by Swain (1978) in the Lake Superior watershed showed significant levels of persistent organic compounds in fish and water samples taken from a lake on Isle Royale, a location removed from usual human activity. He related these contaminants to atmospheric sources. An example of the significance of the atmospheric route is shown in Table 1 for metal inputs to Lake Michigan.

TABLE 1. Trace Element Inputs (10^3 Kg Yr^{-1}) by Major Routes to Lake Michigan (adapted from Allen and Halley, 1980)

	Atmospheric	Tributaries	Erosion
Cd	11	12	75
Cu	120	230	540
Pb	640	180	240
Zn	1100	500	1800

Accurate loading estimates, particularly of toxic materials, are still not available and sources are not adequately identified.

The Science Advisory Board has investigated the feasibility of using radioisotopes of lead and sulphur to identify sources. Under the Board's sponsorship, the Air Pollution Indicators Task Force is also reviewing 40 deposition networks currently in place in Great Lakes studies of toxic substances, trace metals, and other ionic species.

Observations with regard to the comparability of collection, extraction and analysis of atmospheric samples used by the networks in a number of special studies in the Great Lakes region are presented here. A discussion of the techniques and methodologies will be provided in a subsequent report of the Task Force.

The precipitation collectors used in the Great Lakes region differ with respect to collecting surface materials, sampling duration and sample preservation, although there are only three basic types - bulk, wet only and wet/dry. For airborne particulate matter and gaseous compounds, the networks were found to use integrative collection methods whenever major ions, metals and organics were measured. Only a few special studies either used continuous monitors or flux measurement techniques.

The methods used for major ion analysis were generally found to provide good sensitivity, however, it varied between laboratories depending upon the analytical protocol, reagents and instrumentation used. Intercomparison studies will be used to establish compatibility in results obtained.

Conversely, it was found that the metal analysis data were not comparable because of poorly defined analytical procedures. This could lead to errors of interpretation.

A multi-stage process consisting of extraction, fractionation and separation is used for organic measurements and requires methodological development for all atmospheric components including precipitation, airborne particles and vapour phase organics. The measurement protocol for organic compounds needs to be developed before reliable results are obtained and routine atmospheric monitoring considered.

This Task Force is planning a workshop for scientific experts to discuss the issues and present conditions for measurements of atmospheric deposition in the Great Lakes.

Based on a review of measurement and analytical techniques used by the atmospheric deposition networks and special studies on the Great Lakes Basin, it is concluded that the analytical data are not available and cannot offer comparable organic and metal loadings to the open waters of the Great Lakes. However, the techniques for measuring major ions in precipitation and air particulate matter are sufficient to provide adequate precision and good sensitivity. Intercomparison studies will establish uniformity in data accumulation.

It is therefore recommended that:

- MORE RESEARCH BE DIRECTED TOWARD THE DEVELOPMENT OF A STANDARD PROTOCOL FOR MEASURING ORGANICS IN ALL OF THE ATMOSPHERIC COMPONENTS, INCLUDING PRECIPITATION, AIRBORNE PARTICLES AND VAPOUR PHASE ORGANICS;

- A STANDARD PROTOCOL FOR MEASURING METAL IONS BE ESTABLISHED WHICH INCLUDES THE IDENTIFICATION OF A PREFERRED DIGESTION AND INSTRUMENTATION TECHNIQUE; AND

- INTERCOMPARISON STUDIES BE INITIATED TO ASSESS THE COMPARABILITY OF METHODS, ANALYSIS AND LABORATORIES EMPLOYED BY THE ATMOSPHERIC DEPOSITION MONITORING NETWORKS MEASURING MAJOR IONS.

1.3 ECOLOGICAL EFFECTS OF SEDIMENT CONTAMINANTS

Sediments are a significant trap as well as a source for both nutrients and toxics in the Great Lakes. The role of sediments in nutrient management strategies and the feasibility of remedial actions for toxics control is poorly understood. Sediments contaminated with toxic substances can seriously impact bottom dwelling organisms either by reducing populations due to toxicity or causing the organisms to have elevated body burdens, thus contributing to aquatic food chain bioaccumulation.

The issue of in situ sediments was referred to the Science Advisory Board by the Water Quality Board since it was considered beyond the scope of the Dredging Subcommittee. Therefore, a Task Force was established to address the issue of contaminated sediments in areas of impaired use in the Great Lakes and specifically to:

- provide the IJC with an assessment of the effects of sediment contaminants on biota and water quality;

- recommend measures to the parties to improve the Great Lakes quality of life; and

- identify gaps in knowledge and to suggest appropriate investigations.

To achieve these objectives, the Task Force called for an international workshop and proceedings to be used in producing a report to the IJC and in its representations to the Science Advisory Board proposed that the workshop be conducted at an international level for the following reasons:

- the problem of sediment contamination is an important issue of worldwide scope;

- the problem of harbour clean-up and improvement is one of current significance in European industrial nations as well as in North America; and

- expertise exists in both North America and Europe and an open dialogue between scientists, both natural and social, from both continents is mutually beneficial.

The workshop was held in Aberystwyth at the University of Wales with the support of the Science Advisory Board and the Commission, and co-sponsored by the Department of Fisheries and Oceans (Canada), and the National Oceanic and Atmospheric Administration (U.S.A). The workshop was also supported by the Universities of Wales, Amsterdam and Geneva, by Centro Ricerche Energia Ambiente S. Teresa (ENEA), from Italy and the Welsh Water Authority. The response to the workshop by participants of all the nations involved was enthusiastic, and the Science Advisory Board is encouraged to recommend the continuation of this type of information exchange for addressing problems facing the Great Lakes.

The printing of the Proceedings is scheduled for August 1985 when complete recommendations will be forthcoming.

It was generally concluded from these discussions that: i) the workshop was able to assess in general terms the likely effects of sediment contaminants on the biota and water quality, ii) although some ramifications can be theorized, the information is absent regarding the social implications, and iii) recommendations on data gaps and the need for investigations can be supplied, but remedies can only be derived on a case by case basis following adequate investigations.

The Task Force is proposing that its future activities be to visit Areas of Concern and identify remedial options, their feasibility and ramifications. On the basis of this synopsis the following recommendations can be made:

- THAT THE PARTIES EMBARK ON DEVELOPING MANAGEMENT STRATEGIES FOR THE IMPROVEMENT OF TWO AREAS OF CONCERN, AND RECORD BIOLOGICAL PROCESSES OCCURRING DURING THE RECOVERY OF THE SYSTEMS.

- AS ADJUNCT TO THE PRECEDING RECOMMENDATION THE PARTIES SHOULD PROCEED WITH AN IMMEDIATE FULL SCALE SOCIAL AND ECONOMIC ASSESSMENT OF THE AREAS OF CONCERN SELECTED.

2. Ecosystem Responses and Health

Materials entering the Lakes are of concern with regard to the effect they have on the ecology of the Great Lakes. Therefore, methods of measuring and quantifying ecosystem responses and developing an understanding of the processes involved is critical in assuring the "health" of the Great Lakes. Effort is required to assess integrated ecosystem responses to the impacts from man's activities in the Great Lakes Basin. The Science Advisory Board is investigating new approaches to quantify "critical" components of the Great Lakes ecosystem.

2.1 HEALTH OF AQUATIC COMMUNITIES

Background

The effects of eutrophication spurred acceleration of research in the 1960's, yet much basic information on Great Lakes biota remains unavailable. Robertson (1984) noted that for two major aquatic communities, the zooplankton and zoobenthos, species occurrence is described for only a few taxonomic groups and that for others neither spatial nor temporal distribution nor the factors responsible are well understood. It follows that before responses to anthropogenic changes can be understood in Great Lakes aquatic communities, a better knowledge of the biology of many biotic groups is required.

While information is available on the responses of a few major groups of aquatic organisms to eutrophication in the Great Lakes, particularly with regard to phosphorus, such is not the case for persistent toxic substances. These substances are perceived as detrimental but their effects on the health of biota are poorly known. Until environmental interactions and pathways are established, the development of the most effective remedial measures is at best difficult. Furthermore, because these contaminants have a long retention time within the Great Lakes Basin, they will continue to exert their effects long after control measures are implemented.

Thousands of chemicals are being produced and used in consumer goods and industrial applications each year. For most substances, particularly organic chemicals, the toxicological information base is limited and the risks are not established.

Environmental significance has been established for a comparatively few substances. In these instances, available scientific information has provided a defensible basis for future development of water quality criteria. However, the establishment of water quality criteria is slow. Concern exists on the adequacy of the "one chemical at a time" approach to the toxic substances issue. Moreover, water quality criteria are based on single contaminants tested on single species. There are questions as to the applicability of this type of bioassay to the myriad of exotic organic chemicals being introduced into the environment in mixed effluents.

In 1982, the Science Advisory Board conducted a review of research activities related to Great Lakes environmental problems. A result of this review was the establishment of the Health of Aquatic Communities Task Force charged with an investigation of the adequacy of research efforts on the health of living aquatic systems.

The Health of Aquatic Communities Task Force concluded that the results of the original 1982 questionnaire remain valid, i.e., research efforts appeared to be insufficient to adequately address the potential and actual effects of persistent toxic substances on the health of Great Lakes aquatic communities.

With the completion of this first activity, the Task Force initiated two new activities. The first activity was the development of a contract whose primary objective was a literature review of the known effects of persistent toxic substances on the health of Great Lakes aquatic communities. This activity, was conducted in two phases, an initial focus on the published literature and a follow-up on the unpublished literature. The second activity was the formation of a Steering Committee charged with the development of a Symposium/Workshop to address the development of methodologies for assessing the effects of toxic substances on Great Lakes biota.

Literature Review

The results of the two literature review contracts will form the report of the Health of Aquatic Communities Task Force entitled "Assessment of the Effects of Persistent Toxic Substances on Great Lakes Biota". A synopsis of the report is included here and the reader is referred to the full report for more detailed information. The report concluded that relatively little is known about the effects of persistent toxic substances on the health of Great Lakes aquatic communities. Only a few organisms and responses have been studied and only a limited number of persistent toxic compounds have been investigated. Moreover, site-specific studies including Areas of Concern have rarely addressed the effects of toxic substances on the health of aquatic communities. Only a few

studies have been undertaken to assess the effects of specific persistent toxic substances on Great Lakes biota (Table 2). The studies have addressed only a small number of toxic substances (alone or in combination) and most of the Great Lakes species have not been investigated.

Based on the review of Great Lakes studies on structural and functional responses to persistent toxic substances, a number of antecedent, ongoing and potential contamination problems have been identified and are outlined in Table 3.

In addition to the biota-specific studies outlined in Table 3, conditions of acute toxicity and mutagenic activity have been shown in samples at specific locations in the Great Lakes. Dutka and Switzer-House (1978) reported that, based on the Spirillum volutans test, acute toxicants were present in the Rochester area, Welland Canal area, Toronto Harbour and Hamilton Harbour of Lake Ontario. Based on the Ames' test, researchers showed mutagenic activity to be present in Toronto Harbour, Hamilton Harbour, Niagara River mouth and Bay of Quinte of Lake Ontario (Dutka and Switzer-House, 1978) as well as in the Buffalo River of Lake Erie (Black et al., 1980).

It is reasonable to assume that concentrations of persistent toxic chemicals have had significant effects on the health of Great Lakes aquatic populations. This is particularly valid for localized areas near sources of pollutant input, such as the 39 "Areas of Concern" identified by IJC (1981). Furthermore, it is possible, though not well documented, that lakewide effects have occurred due to high ambient concentrations of toxic chemicals, e.g., chlorinated organic contamination of Lake Michigan, and reproductive failure of planted lake trout as suggested by Willford et al. (1981) as well as in the reproductive failure in fish-eating bird colonies in the early 1970's in Lake Ontario, as demonstrated by Weseloh et al. (1984).

Numerous tests have been developed to assess functional responses of aquatic communities to persistent toxic substances. Those used in Great Lakes studies are summarized by biotic group in Table 4.

The use of an indicator species based on species-specific sensitivity or adaptive potential, or the use of a particular community structure or composition index to delineate detrimental impacts on aquatic biota due to a specific toxic contaminant, or contaminant class or group of contaminants, was not found in the literature. However, pattern recognition techniques such as reciprocal averaging, ordination and discriminant analysis have been used in recent studies to investigate the more specific underlying causes of pollution, and the biological consequences (Crowther and Luoma, 1984). It is clear that refinement and development of methodologies for assessing the effects of toxic substances on Great Lakes biota is necessary.

TABLE 2. SUMMARY OF GREAT LAKES STUDIES ON RESPONSES TO SPECIFIC TOXIC SUBSTANCES ON BIOTIC GROUP

BIOTIC GROUP	STUDY REFERENCE*	TOXIC SUBSTANCE
Bacteria	Pfister et al. (1970)	Aldrin, Endrin, Dieldrin
Fungi	Tews (1971)	Fungicides (Captan, Dexon, Dithane, Terrachlor, Thiram, Zineb) and Soil Fumigants (Vapam, Vorlex)
Phytoplankton	Marshall and Mellinger (1980)	Cadmium
	Glooschenko (1971)	DDT and Dieldrin
	Glooschenko and Glooschenko (1975) Ledermann and Rhee (1982) Lin and Simmons (1981) McNaught et al. (1980)	PCBs
Zooplankton	Borgmann et al. (1980)	Cadmium, Copper, Mercury, Lead, Arsenic
	McNaught et al. (1980)	PCBs
Benthos	Borgmann et al. (1978)	Lead
Fish	Willford et al. (1981) Stauffer (1979)	PCBs, DDE
	Letherland and Sonstegard (1978)	PCBs, Mirex
Birds	Gilman et al. (1978)	PCBs, DDE, Mirex, Photomirex, Hexachlorobenzene
Mammals	Aulerich and Ringer (1977)	PCBs

*References in Report of Health of Aquatic Communities Task Force

TABLE 3. SUMMARY FINDINGS OF GREAT LAKES RESEARCH ON EFFECTS OF PERSISTENT TOXIC CONTAMINANTS BASED ON BIOTIC GROUP

BIOTIC GROUP	RESEARCH FINDING	REFERENCE*
Phytoplankton	Ambient concentrations of PCBs and their metabolites may have a slight effect on the Saginaw Bay nannoplankton community	McNaught et al. (1980)
	Sediment-associated contaminants from the Niagara River may affect adjacent Lake Ontario phytoplankton productivity	Munawar et al. (1980)
	Ambient cadmium concentrations in Lake Michigan may have a small effect on phytoplankton community structure and productivity	Marshall and Mellinger (1980)
Zooplankton	Zooplankton grazing may be inhibited in Saginaw Bay and to a lesser extent in Lake Erie, likely due to PCBs and their metabolites	McNaught et al. (1980)
	Many harbour sediments have been shown to be toxic to zooplankton test species	Prater and Anderson (1977)
	Ambient cadmium concentrations in Lake Michigan may have a small effect on zooplankton community structure and productivity	Marshall and Mellinger (1980)
Benthos	Deformed benthic invertebrates have been found near the Detroit and Maumee River mouths and Thunder Bay, Lake Superior	Brinkhurst et al. (1968); Warwick (1980); Crowther and Luoma (1984)
	Many harbour sediments have been shown to be toxic to benthic invertebrate test species	Gannon and Beeton (1969); Prater and Anderson (1977)

*References in Report of Health of Aquatic Communities Task Force

continued

TABLE 3. Continued.

BIOTIC GROUP	RESEARCH FINDING	REFERENCE*
Fish	Significant cumulative mortality has occurred for lake trout fry exposed to ambient Lake Michigan concentrations of PCBs and DDE	Berlin et al. (1981)
	A significant lower survival of lake trout eggs has occurred when incubated in Lake Michigan water and in Lake Huron water	Stauffer (1979); Edsall and and Mac (1982); Mac et al. (1981)
	Concentrations of tributyltin in certain harbours and marinas in the Great Lakes are likely high enough to exert a chronic stress on local fish populations	Maguire et al. (1982)
	Disease frequency in fish was high in the Fox River, likely due to contamination stress	Brown et al. (1979)
	Sauger reproduction does not occur, and survival of the walleye population is also affected, in Torch Lake on Keweenaw Peninsula, likely due to exposure to copper tailings	Black et al. (1982)
	Fish have exhibited avoidance reactions to pulp and paper mill effluents	Ryder (1968); Kelso (1977)
	Increased rate of hyperplasia has been found in the Fox River flowing to Saginaw Bay; the Black and Buffalo Rivers flowing into Lake Erie; and in Torch Lake on Keweena Peninsula	Brown et al. (1973); Black et al. (1980, 1982); Baumann et al. (1982)

*References in Report of Health of Aquatic Communities Task Force

continued

TABLE 3. Concluded.

BIOTIC GROUP	RESEARCH FINDING	REFERENCE*
Birds	High reproductive rates of fish-eating bird colonies are normal in the Great Lakes, with the exception of Lake Superior, where reproductive success of herring gull colonies has recently decreased	Mineau et al. (1984)
	Reproduction in Forster's tern colonies in Green Bay are considered inadequate for population maintenance	Toxic Substances Task Force (1983)
	Abnormal nesting behaviour had been exhibited by adult herring gulls in the early 1970's	Fox et al. (1973)
	A high incidence of congenital anomalies occurred in chicks of some species of fish-eating birds in Lake Ontario colonies in the early 1970's	Gilbertson et al. (1976)
	The incidence of congenital anomalies is currently normal in Lake Ontario colonies	Gilbertson (1983)
Mammals	Feeding of Lakes Huron and Michigan fish to mink resulted in adult mortality and/or kit mortality	Aulerich and Ringer (1977); Hornshaw et al. (1983)
	Feeding of Lake Ontario, Erie and Michigan coho salmon to rats caused growth retardation and thyroid enlargement	Sonstegard and Leatherland (1978); Leatherland and Sonstegard (1980)

*References in Report of Health of Aquatic Communities Task Force

TABLE 4. FUNCTION RESPONSE TESTS USED IN GREAT LAKES STUDIES

BIOTIC GROUP	TEST DESCRIPTION	REFERENCE*
A. PHYSIOLOGICAL RESPONSE		
Bacteria	Spirillum volutans test for acute toxicants	Dutka and Switzer-House (1978)
Phytoplankton	Algal fractionation bioassay	Munawar et al. (1983)
	In situ enclosures or container bioassays (ecosystem approach)	Marshall and Mellinger (1980); McNaught et al. (1980); Glooschenko (1971);
	Natural community bioassay	Simmons (1981)
	Site water or sediment bioassay	Gannon and Beeton (1969)
Zooplankton	In situ large enclosures or container bioassays (ecosystem approach)	Marshall and Mellinger (1978, 1980); Marshall et al. (1981); McNaught et al. (1980)
	Natural community bioassay	Borgmann et al. (1980)
	Site water or sediment bioassay	Gannon and Beeton (1969); Prater and Anderson (1977)
	Zooplankton grazing assays	McNaught et al. (1980)
Benthos	Sediment bioassay	Gannon and Beeton (1969); Prater and Anderson (1977)
	Sediment selectivity assays	Gannon and Beeton (1969)
Fish	Fish egg hatchability	Mac et al. (1981)
	In situ fish egg survival	Stauffer (1979); Mac et al. (1981); Mac et al. (1982); Edsall and Mac (1982)

*References in Report of Health of Aquatic Communities Task Force

continued

TABLE 4. Continued.

BIOTIC GROUP	TEST DESCRIPTION	REFERENCE*
A. PHYSIOLOGICAL RESPONSE		
Fish	Fish disease assays	Brown *et al.* (1979)
	Assay of contaminated diets	Hilton *et al.* (1983)
	Amino levulinic acid dehydratase induction	Hodson *et al.* (1977, 1983)
	Allantoninase induction	Passino (1981)
	RNA/DNA ratio	Kearns and Atchison (1979)
Birds	Breeding success of colonial birds	Keith (1966); Gilbertson (1974)
	Electronic sensing of embryonic motility	Mineau *et al.* (1984)
	Aryl hydrocarbon hydroxylase induction	Mineau *et al.* (1984)
	Egg exchange experiments	Fox *et al.* (1975, 1978)
B. BEHAVIORAL RESPONSE		
Fish	Radio telemetry for *in situ* avoidance/preference	Kelso (1977)
Birds	Time off nest determinations	Fox *et al.* (1978)

*References in Report of Health of Aquatic Communities Task Force

continued

TABLE 4. Concluded.

BIOTIC GROUP	TEST DESCRIPTION	REFERENCE*
C. GENETIC RESPONSE		
Bacteria	Ames' Test	Dutka and Switzer-House (1978)
Benthos	Incidence of deformed chironomid larvae	Warwick (1980)
Fish	Incidence of hyperplasia and neoplasia	Sonstegard and Leatherland (1975); Brown et al. (1973); Black et al. (1980); Baumann et al. (1982)
	Levels of thyroxine and triidothyronine	Leatherland and Sonstegard (1978)
Birds	Incidence of congenital anomalies	Gilbertson et al. (1976)

*References in Report of Health of Aquatic Communities Task Force

2.2 HUMAN HEALTH EFFECTS

The ultimate objective of Great Lakes water quality programs, including monitoring and surveillance, research and regulations is to protect the health of aquatic populations and public health. The latter is the primary objective of the Human Health Effects Committee. By conducting monitoring and surveillance, scientists are able to identify harmful contaminants, determine their sources and measure their concentrations. By conducting research or reviewing data, scientists can assess the potential effects of these chemicals on human health and predict their impact on exposed populations. Epidemiologic and health risk assessments for chemicals of concern can provide a perspective for formulating water quality objectives and regulations.

Current activities include:

2.2.1. Great Lakes Chemicals: Evaluation of 1978 Appendix "E" Chemicals

Establishment of Interim Maximum Daily Exposure Limits

The major thrust of the Committee's exercise has been to identify those chemicals which are a cause for concern to human health because of their toxicity and their levels in lake water or fish. To accomplish this objective, the Committee has derived Interim Maximum Daily Exposure Limits from all sources by using existing values of Virtually Safe Dose (VSD) and Acceptable Daily Intake (ADI), or by applying safety factors to no-observed adverse effect levels when VSD and ADI values were not available. The chemicals which may be a cause for concern, as well as those that may not, are identified in the report of the Health Effects Committee.

2.2.2 Great Lakes Chemicals: Toxicity Profiles of the 1983 Inventory Chemicals

The Committee considered the need to prepare toxicity profiles for newly identified contaminants detected in the Great Lakes Basin ecosystem and the priorization of these chemicals according to previously established procedures. At present, over 100 such profiles have been prepared under a contract with Health and Welfare Canada and others are being prepared.

2.2.3 Lead in Edible Portions of Great Lakes Fish

The data for St. Lawrence River fish indicate that lead is present in both organic and inorganic forms. If, apart from organic lead, inorganic lead were present at the same

level, 30 g of fish per day would introduce 60 µg of inorganic lead per day into the diet. Since the estimated daily intake of lead from normal diet (including both food and water) ranges from 60 to 250 µg per day, the additional inorganic lead burden from fish would result in an upper bound total intake of 2.2 mg lead per week, which is within the World Health Organization estimate of a tolerable intake of 3 mg per person per week.

Taking into account that both organic and inorganic lead are likely to be present in fish, then the concentration of total lead in the edible portion of fish (based on long term consumption of 30 g of fish per day per adult) should not exceed 2 mg/kg lead (combined organic and inorganic forms). A lower limit would apply to children and to women of childbearing age.

These limits should be considered tentative and subject to possible change as more information becomes available on: (1) the level and frequency of both inorganic and organic lead in fish; (2) the organic lead content of other food; and (3) the toxicity of alkyl lead.

Whereas monitoring for total lead content may be sufficient for regulatory purposes, it remains necessary to determine the chemical species of lead, including changes in speciation of organic lead with time, for a toxicological evaluation. Information on the type of discharge (continuous vs. discontinuous) would also be useful to those who evaluate the data.

2.2.4 Epidemiology

In order to stimulate epidemiologic research that would help the IJC with its mandate of evaluating health effects of water contamination, the Committee requested and received a budget from the IJC and has obtained expert consultation in epidemiology.

2.2.5 Drinking Water

In March 1983, the Health Effects Committee developed a water quality monitoring questionnaire and sent it to all Great Lakes States and the Province of Ontario to assess existing state or provincial efforts to monitor raw and treated water as well as industrial effluents. Information received was correlated and condensed into a matrix suitable for identification of water surveillance programs. The results were then returned to the jurisdictions for verification and updating with the final results summarized in the report of Health Effects Committee.

Therefore it is recommended that:

- THE JURISDICTIONS SHOULD CONTINUE TO MONITOR LEAD CONCENTRATIONS IN FISH IN THE ST. LAWRENCE RIVER SO THAT POTENTIAL HUMAN EXPOSURE CAN BE ASSESSED MORE RELIABLY AND CHANGES IN POTENTIAL EXPOSURE NOTED.

- THE JURISDICTIONS SHOULD ANALYZE THE EDIBLE PORTIONS OF FISH FOR BOTH ORGANIC AND INORGANIC SPECIES OF LEAD AND PROVIDE AGE AND SPECIES INFORMATION.

3. Ecosystem Management and Remedial Activities

The third major component of the Science Advisory Board's program is the investigation of the techniques used in ecosystem management. Chapter 1 addressed scientific and research requirements in identifying sources and inputs to the Lakes, Chapter 2 to assessing the impacts of these inputs. Finally, the Board is addressing the ways these inputs can be managed and the effects minimized. At the present time, the main management tools are water quality models and water quality objectives. While the Board realizes that these approaches are currently necessary, there is considerable concern about their adequacy and utility. A major weakness of past strategies that the ecosystem approach attempts to rectify is to incorporate socio-economic considerations into all appropriate activities. Accordingly, the Board is investigating a number of initiatives.

3.1 SOCIAL AND ECONOMIC CONSIDERATIONS COMMITTEE

In 1984 the Social and Economic Considerations Committee proceeded to work in three areas 1) institutional arrangements; 2) educators network; and 3) economic & non-economic valuing.

Institutional Arrangements

Introduction

Adoption of an "ecosystem approach" for dealing with Great Lakes water quality and related issues requires a more "holistic" systems perspective to guide research and management. Attempts at ecosystem rehabilitation are confronted with a dilemma: any attempt at comprehensive management must accept existing multi-institutional arrangements and try to implement plans and policies within these existing arrangements. But to accept existing institutional arrangements is to accept a structural distribution of discretion that seems to preclude comprehensive management. Attempts to overcome this dilemma have led to the call for "consensus management".

The Great Lakes Ecosystem Rehabilitation studies, which used Green Bay as a case example, concluded that successful implementation of any ecosystem plan will depend upon some form of consensus management, because no single agency or institution has either the responsibility or the authority for the whole ecosystem.

The Green Bay Experience

A "Future of the Bay" (FOB) program being carried out under the Bay Lake Regional Planning Commission (BLRPC) is striving to promote greater agency cooperation and coordination in the planning and management of activities related to the Green Bay ecosystem.

The study: (1) reviewed the FOB experience; (2) developed a normative, operational model based on this experience to assist future efforts in multi-organizational planning and management; and (3) reviewed the conceptual and theoretical literature on consensus management strategies.

The more generalized model, which describes the FOB experience to date, contains a number of sequential steps in the process each of which may be viewed as a model component. This model can be summarized:

1. Motivation: In a multi-institutional context a catalyst must provoke the effort of collaborative planning. In the case of FOB the catalyst was the advent in 1981 of a new national administration and the perception of a threatened reduction in federal dollars. Each agency was similarly situated with respect to the perceived external threat; it was to no single agency's advantage to play a hold-out strategy. The important point here is that deterioration of the Green Bay ecosystem was not in itself sufficient to motivate agencies to work together.

2. Emergent leadership: While groups naturally tend toward the identification of a leader, the FOB experience suggests three things: (a) in a collaborative planning process <u>weak leadership</u> is the norm even though strong leadership may be required to make it work; (b) the cost in time, effort, and opportunities foregone of reaching a collaborative decision is high; (c) the longer it takes the collaborative group to reach a decision, the higher the probability that decisions will be made elsewhere, outside the collaborative group, by institutions with broad authority.

3. The nature and variety of membership: In the case of FOB the major players are policymakers and decisionmakers, those with line authority and the capability to act. This is a strength but it poses several problems as well. The strength is that the members are those who can make decisions if they want to or have to. The problems have to do with: voluntary participation and the distribution of discretion; hidden hierarchies of power and informal structures of influence; the number, variety, and heterogeneity of institutional actors; and mutual knowledge needs.

4. Establish legitimacy: The FOB experience reaffirms the political principle that any program of collaborative planning must pay conscious and constant attention to securing and maintaining legitimacy and must devise strategy and tactics to do so.

These steps, as illustrated by the FOB experience are consistent with a body of literature on organizational theory. With specific reference to the FOB, the following observations were made.

(1) As an organization FOB is an advisory body and as such, it has a number of characteristic weaknesses. Nevertheless, a major plus is that the member institutions got together in the first place. (2) The level of participation in FOB has been mixed. (3) The annual Future of the Bay conferences have been successful. (4) The Bay Lake Regional Planning Commission, the lead agency in FOB, has performed credibly but FOB needs political and financial support. (5) The requirement of consensus decision making is a basic weakness. In summary, FOB is not a means to comprehensive ecosystem management based on rehabilitative strategies.

Theoretical Issues and Other Case Studies

The theoretical literature begins with skepticism about the potential of consensus management and ends with the abandonment of the concept of consensus and with the call for authority to overcome the intrinsic dilemmas of consensus. These difficulties, each of which is a structural barrier to consensus, were categorized as follows: (1) The distribution of discretion; (2) "Free Rider" problem; (3) Consensus and the calculus of self-interest; (4) Dilemmas of cost/benefit structure: (a) deprivation cost; (b) opportunity cost; (c) the cost of authority; and, (5) The rationality of inhibiting rational management.

The chief lesson that the theoretical literature has to teach us is that structure is <u>what</u> governs and structure is not neutral; it is biased toward some approaches to management and against others. The existing structure of authority is biased against successful consensus management.

Six case studies from the literature reported on the application of consensus management in practice. The locations of these studies are: Gray's Harbor, Washington and Coos Bay, Oregon (Davis 1980); San Francisco Bay, California (Caplenas, 1982); Irvine, California (Belknap, 1980); and the Norfolk Broads, England (O'Riordan, 1978).

The propositions of the theoretical literature are borne out in the case studies. In theory and in practice, it appears, the probability is slight that ecosystems can be successfully managed through consensus. This does not mean that there is no role for consensus strategies in ecosystem management. It is reasonable to speculate that such strategies might prove useful in building support and legitimacy for programs of ecosystem rehabilitation.

The literature leads to the additional conclusion that legislative strategies which aim to make ecosystem rehabilitation the context for management are a necessary but not sufficient part of any comprehensive approach to ecosystem rehabilitation.

Conceptual Scheme of Ecosystem Management: Political and Economic Realities

The model of the Green Bay ecosystem resource base and the political and economic control system is characterized by mutual interactions among a number of components in a dynamic system. It is intended as a descriptive tool and as an aid in comprehending the many interrelated forces that work to determine what ecosystem management will be. In addition, the model is intended to stimulate the imagination toward discovering important general problems and possible avenues toward resolution.

Ecosystem management and politics depend on five sets of variables: (1) the ecological status and dimensions of the ecosystem resource base; (2) user interactions and market forces; (3) affected publics and their identification of problems; (4) the general political setting; and, (5) the policy areas and intergovernmental management context.

The research program presented rests on two general propositions: First, research aimed at providing a basis for the improvement of institutional performance must be directed to the study of institutional behaviour as well as institutional structure. Second, research aimed at assessing institutional performance must do three things: (a) Identify the criteria to be used to judge the movement toward the goal of ecosystem rehabilitation. (b) Research how existing institutions behave. (c) Apply criteria for judgement to the findings of institutional behaviour in order to identify inadequacies in performance. These inadequacies in performance should be viewed as areas deserving of additional research attention.

Another contract has been let to do a similar comparative case study on Essex County, Ontario.

The goal is to find ways to translate ecological criteria into institutional measures of success; to have the established criteria for judgement become an institutionalized element in a program of ecosystem rehabilitation. Research on these questions would represent an important extension of the state-of-the-art in the analysis of ecosystem management and politics, and would be applicable to the study of ecosystem rehabilitaton in Green Bay, elsewhere in the Great Lakes, and beyond.

Educators' Network

In October 1984, questionnaires were sent out to teachers, publishers and editors. The questionnaire was developed with the idea that if the Great Lakes ecosystem is to be preserved for future generations to use and enjoy, current and upcoming students must learn to value and respect that system.

The survey was designed to help educators share their teaching resources whether it be in science, geography, literature classes, special enrichment assignments, research or credit work, complete units, infusion units or through problem solving in unrelated coursework. More than one-third of the recipients responded which showed a great deal of interest on behalf of the educators and publishers of Great Lakes information.

The Educators' Network Work Group met in January 1985 to review the responses. They expressed interest in compiling a directory of all Great Lakes Educators Source Materials and another listing newletters, audio-visual materials and sources used for obtaining information for teachers.

Other organizations will be advised in implementing future programs as the Work Group itself will act as a catalyst only to identify recommendations.

Economic and Non-Economic Valuing

Progress is being made in restoring water quality in the Great Lakes as a result of concerted activities carried out by the United States and Canada under the Great Lakes Water Quality Agreement. Currently, however, a number of more difficult "Areas of Concern" identified by the Water Quality Board remain. Special efforts may be needed to deal with these. At the same time, the current economic recession has led to constraints on public spending as well as to a more generalized reaction against government regulatory measures of all kinds. The additional investments and regulatory enforcement required for the Great Lakes may well need more "justifications" to decision makers in order to have the funding authorized and programs maintained. In addition, valuation of benefits should be a component of policy analysis or program evaluation.

One widely recognized difficulty is that of placing values or weights on the direct and indirect social benefits associated with high environmental quality. Expenditures under the Water Quality Agreement are made to obtain such benefits, hence, "valuation" of current and anticipated results from this Agreement work may well be a pre-requisite to maintaining the political will and support to continue.

There is extensive literature on "valuation" and considerable debate about the theoretical soundness, applicability, and reliability of various economic and non-economic analytical approaches and/or applied techniques used or proposed. The purpose of this project is to have a critical review made of this literature by people familiar with its different components. The intent is not to promote the use of one particular approach or technique, nor to attempt to "measure" benefits from the Great Lakes. Rather, it is to help fulfill the Science Advisory Board's mandate to keep abreast of state-of-the-art issues as they may relate to fulfilling the intent of the Agreement, and advising on specific research needs related to Agreement activities.

Three individual contracts have been let by the Social and Economic Considerations Committee. Their objective is to describe for the benefit of non-specialists and to critically review, valuation or weighting methodologies in the (1) Economics Field; (2) Urban Planning and Landscape Architecture; and (3) Social Psychology and Social Impact Assessment.

These contracts are to be completed in two phases. Phase 1 is to produce a work outline which is to be reviewed and approved by the Committee before each contractor proceeds to Phase 2. Phase 2 is to produce a final report.

3.2 AQUATIC ECOSYSTEM OBJECTIVES

General and specific objectives to protect the waters of the Great Lakes system have been identified in both Agreements. The 1978 Agreement contained specific objectives revised from 1972, which remained limited to those parameters whose effects on ecosystem health were relatively well documented. The 1978 Agreement also contains a number of general objectives which were intended to provide aesthetic or other non-quantifiable protection to the system. Under the 1978 Agreement, the Parties may amend the list of specific objectives by addition or through the revision of existing objectives by incorporating more recent scientific data; they may also amend the general objectives (or other parts of the Agreement) as they deem necessary.

The Science Advisory Board established the Aquatic Ecosystem Objectives Committee (AEOC) in order to consider these objectives and to make recommendations concerning them to the Board. Since its inception in 1980, the AEOC has developed seven new objectives and revised thirteen existing objectives. These objectives, however, have not yet been appended to the Agreement although the Commission has recommended them to the two Parties.

The 1978 Agreement broadened the scope of objectives to include ecosystem quality to accommodate the increasing concern that water quality objectives were based essentially on the independent effects of individual parameters without consideration of the interactions among mixtures of parameters or of the interdependence of all components of the ecosystem. The AEOC established a Work Group on Indicators of Ecosystem Quality and charged them with the task of describing such indicators, with particular attention to the use of the lake trout as the indicator organism. The Work Group submitted its report to the AEOC in 1985.

3.2.1. Chemical Objectives

The Federal Parties are required by the Agreement to urge the regulatory jurisdictions to "ensure" that standards or other such legal instruments are "consistent" with these objectives. The AEOC considers the Agreement objectives to be the goals only when and where they have been exceeded in the system; they are not such where existing water quality is better than the objective limits described. The achievement of the objectives or the maintenance of the existing water quality, may be accomplished through the limitation of loadings of the substance in question as required in the Agreement.

Since its 1983 report, the AEOC has developed objectives for ammonia, lindane and toxaphene.

3.2.2. Ecosystem objectives.

The AEOC is also investigating the use of biological measures or indicators of ecosystem health--for the oligotrophic system in Lake Superior (and elsewhere) as well as other systems in other lake basins.

The Lake Trout objective is fully discussed in a report entitled "A Conceptual Approach for the Application of Biological Indicators for the Determination of Ecosystem Quality in the Great Lakes Basin". The report, which has received considerable external review, discusses the applicability of the indicator or surrogate concept within the context of the ecosystem approach. The report contains general criteria for the use of indicator species and the specific rationale for using the lake trout as an indicator species for oligotrophic Great Lakes ecosystems.

The Work Group's report provides a comprehensive overview of the critical elements known to control population dynamics of the lake trout. Such elements include: stocking/culture of lake trout and their competitors; sea lamprey control; influence of exotic species; habitat restoration and protection; and, of course, water quality management. In these traditional areas of determining the status of fish health and in others like community interaction and biochemical indicators of stress, a need for more knowledge and hence research options are noted. Thus, the report provides the background for recommending a general ecosystem objective and sets forth a methodology for assessing the achievement of a specific, cold water oligotrophic ecosystem objective and the data necessary to determine the progress towards an ideal and healthy Lake Superior.

In order to determine the health of such a specific ecosystem objective for Lake Superior, the Work Group has developed a prototype computer program using the lake trout as the indicator species. This computer program is intended to assist fishery and water quality managers in identifying and integrating ecosystem health. This program was subjected to peer review and further development at a workshop held in Windsor, Ontario. The revised program will be demonstrated to Great Lakes ecosystem managers during the coming year.

Completion of this report and development of the computer program do not conclude the effort on indicators, for, as set forth in the report, the use of other indicator species is clearly warranted. Work on a mesotrophic system in Lake Erie is planned.

Therefore it is recommended that:

- THE AMMONIA OBJECTIVES BE REVISED: THE OPEN WATERS LIMIT FOR AQUATIC LIFE RAISED FROM 0.02 to 0.03 mg/L UN-IONIZED AMMONIA AND THE 0.5 mg/L AMMONIA LIMIT TO PROVIDE FOR EARLIER WATER SUPPLY LIMITS OF THE JURISDICTIONS BE DELETED.

- THE CONCENTRATION OF TOTAL HEXACHLOROCYCLOHEXANE (BHC) ISOMERS IN WATER SHOULD NOT EXCEED 0.02 µg/L FOR THE PROTECTION OF AQUATIC LIFE. THE CONCENTRATION OF TOTAL BHC ISOMERS IN EDIBLE PORTIONS OF FISH SHOULD NOT EXCEED 0.3 mg/kg (WET WEIGHT) FOR THE PROTECTION OF HUMAN CONSUMERS OF FISH.

- WORK BE CONTINUED ON THE FURTHER DEVELOPMENT OF BIOLOGICAL INDICATORS OF ECOSYSTEM HEALTH, SELECTING SPECIES OR COMMUNITIES FOR MESOTROPHIC AND EUTROPHIC SYSTEMS IN ADDITION TO THE LAKE TROUT FOR OLIGOTROPHIC CONDITIONS.

3.2.3. Future Directions

The AEOC is considering the development of objectives for groups of chemicals such as the chlorobenzenes and chlorophenols. The utilization of structure-activity relationships (SAR) in these activities is anticipated, both as predictive aids for estimating toxicity and as means of estimating parameters necessary for the prediction of exposure to these chemicals.

In addition, the Committee has joined with other IJC committees to actively develop the hazard assessment process for Great Lakes contaminants regarding their adverse effects in the ecosystem. This work is being pursued under the auspices of the Coordinating Committee for Great Lakes Chemicals. The development of such data for the chemicals listed in the 1983 Inventory of Great Lakes Chemicals will be an important task of the AEOC and the evaluation of such data represents a shift in focus from the Committee's traditional role of examining toxic effects data for minimum acceptable levels.

3.3 MODELING AND MANAGEMENT

The Board's investigation of modeling has emphasized mathematical representations that address two major issues in the Great Lakes: eutrophication and toxic contaminants. Eutrophication models played a major role in shaping phosphorus loading objectives for the 1978 Agreement. Toxic substances models are just now beginning to get attention as for example in the PCB pollution problem in Lake Michigan's Waukegan Harbor.

The proper use of models may be the most important and cost-effective tool in management of the Great Lakes ecosystem. Ecosystem complexities require some kind of integrating tool that provides a means of describing the interactions among a myriad of system components. Hence, they are irreplaceable in the implementation of an ecosystem management philosophy.

Mathematical models have been used with some success in Great Lakes management, however caution is neccessary in the interpretation of their output since their limitations are not fully understood.

Uncertainties in model results are being stressed and sometimes further quantified. Model validation is also fundamental to proper usage. Both of these activities will elucidate the role that models can serve in Great Lakes management.

Mathematical models, however, are always limited and will not replace sound scientific insight and common sense management. A recently completed inventory and evaluation of Great Lakes models has been prepared for the Board by a special Task Force.

Therefore it is recommended that:

- NEW APPROACHES INVOLVING THE USE OF PERSONAL COMPUTERS, AND THE DEVELOPMENT OF INTELLIGIBLE USER-FRIENDLY SOFTWARE FOR WATER QUALITY MODELING SHOULD BE ENCOURAGED AND FUNDED TO EASE THE TRANSFER OF SCIENTIFIC INFORMATION FROM MODELERS TO MANAGERS AND POLICY MAKERS WHICH HAS BEEN BOTH INEFFICIENT AND INSUFFICIENT.

- THE BUILDING OF NEW MODEL STRUCTURES BE ENCOURAGED AND GREATER SUPPORT BE GIVEN FOR REFINING AND INTEGRATING EXISTING MODELS AS INTEGRATED AND MULTIFACETED GREAT LAKES MODELS.

4. Council on Great Lakes Research

To enchance the ability of the Commission and the Science Advisory Board to provide effective guidance and support for Great Lakes research, the Board recommended that the IJC establish a Council of Great Lakes Research Managers. The Council was established in 1984 with the following objectives:

- to review research relevant to the Great Lakes;
- to identify gaps in scientific knowledge and suggest the kind of research required to provide this knowledge;
- to recommend research priorities to the Science Advisory Board and the Commission;
- to encourage dissemination of scientific information and research results; and
- to assist in the coordination of Great Lakes research programs and develop mechanisms for cost-effective international planning and cooperation.

From the Council's point of view, traditional research reviews are useful, but not sufficient. They can provide the Council with information about the amount and kind of research that may be relevant to the Great Lakes, but will not determine the adequacy of this research in terms of the requirements of the Water Quality Agreement.

In 1985, the Council of Research Managers will hold a workshop to develop appropriate methods for reviewing Great Lakes research, collectively, to determine the extent to which this research is responding to the requirements of the Agreement. These methods have to be scientifically sound in order to be acceptable to all parties involved in Great Lakes research. Therefore, the Council will invite research scientists, managers and administrators to participate in the process.

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